A Reply. Sulphide Mineralization and Wall Rock Alteration at Rødhammeren Mine, Sør-Trøndelag, Norway

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In a recent paper (Nilsen 1971) some problems concerning the origin of the wall rocks and ores at Rødhammeren Mine, Haltdalen were brought about by the present author. I am pleased to see that alternative points of view have been put forward and emphasized by Mr. N. Ø. Olesen based on his studies in the Tydal area. The relationship between the various metamorphic and igneous rocks in the Haltdalen-Tydal area is not clear-cut and I am aware that the conclusions I reached in my paper invited criticism.

Concerning the cordierite-anthophyllite-bearing rocks which were described from the Haltdalen-Tydal area, I agree fully with Olesen in that their occurrence seems to be far more abundant in the Trondheim region than hitherto assumed. Besides their general appearance, within and in the immediate vicinity of the Fongen-Melshogna-Hyllingen igneous complex, similar cummingtonite-anthophyllite rocks have recently been recorded from the Kvikne area in the central Trondheim region (Nilsen & Mukherjee 1972). However, their occurrence seems in general to be restricted to narrow zones within the metamorphic supracrustals of the Cambro-Silurian sequence in the Caledonides.

Cordierite- and anthophyllite-bearing biotite rocks of an undoubtedly contact-metamorphic origin occur immediately to the eastern border of the complex and it is interesting that Olesen has traced this contact zone northwards along the eastern border of the complex. The contact zone has recently been described from the south-eastern Hyllingen complex by Birkeland & Nilsen (1971). Similar rocks have been found by the present author as xenoliths within the Hyllingen complex together with hornfelsic xenoliths of undoubtedly metavolcanic origin, e.g. fine-grained hornblende hornfelses (labradorite-brown hornblende-clinopyroxene) and diopside hornfelses (labradorite-diopside).

Now, their occurrence, their textural characteristics and their mineralogical composition differ in so many places from the cordierite-anthophyllite rocks of the Rødhammeren deposit that Mr. Olesen's pointing to a genetic relation-

ship between the contact metamorphism and the formation of the wall rocks and ores at Rødhammeren cannot remain unchallenged.

In Olesen's opinion the anthophyllite- and cordierite-bearing hornfelses originated as a result of a general Mg-Fe metasomatism subjected to the pelitic rocks undergoing contact metamorphism by the emplacement of the gabbro. To me it is difficult to assume that a dioritic or a monzonitic rest melt should be the source of Mg-bearing hydrothermal solutions. The mineral assemblages generally found in the hornfelses do not reflect any metasomatism involving a Mg-Fe influx from the gabbro. Varieties of the hornfels richer in the ferromagnesian minerals may have been originated by remobilization of elements in a smaller scale within the pelitic rocks undergoing contact metamorphism.

Signs of the progressive contact metamorphism of the metabasites towards the eastern border zone can be seen in the hornblendes which follow a similar trend as described by Miyashiro (1968). In the easternmost parts they have a greyish yellow colour, turning into a darker olive-green colour in the andalusite zone and changes into a dark olive-brown colour in the hornfels zone and in the xenoliths. A progressive An-enrichment in the plagioclases towards the contact can be noticed – going from an oligoclase in the east to a labradorite in the hornfels zone and in the xenoliths.

Now to the point: In the *western* border zone none of the above-mentioned characteristics have been found by the present author among the equivalent rocks. The effect of contact metamorphism by the emplacement of the gabbro has not been found in the areas between Hyllingen and Trælsåfjell and a '... direct genetic relationship between the contact metamorphism and the Mg-Fe metasomatism' in this area is far from evident. Unaltered garnet-quartz-biotite schists occur close to the western contact near the river Skjelåen. The schistose metavolcanics bear none of the above-mentioned signs of a progressive thermal metamorphism towards the contact – they are all andesine/oligoclase amphibolites with a bluish green hornblende.

The cordierite-bearing anthophyllite/gedrite rocks accompanying the ores at Rødhammeren have no textural or mineralogical similarities with the eastern hornfelses. The Rødhammeren anthophyllite/gedrite rocks are medium- to coarse-grained, nearly monomineralic rocks which imply an extremely Mg enrichment compared with the ordinary hornfelses from the eastern border of the igneous complex. They occur within a restricted area, well separated from the gabbro by rocks which do not show any mineralogical or textural features that might indicate the effect of a contact metamorphism. Their relation with the ore genesis seems evident as I pointed out in my paper, but the relationship between the ore deposit and the gabbro cannot by any means be established – whether one assumes a contact metamorphic origin of the wall rocks or not. The ores of the Rødhammeren deposit do not show any features which might point to an affiliation with the gabbro massif, e.g. high nickel content. Recent investigations soon to be published have shown that the Hyllingen magma was deficient with respect

to sulphur but enriched in oxygen. Thus it is difficult to assume that the source of the fluids responsible for the formation of ores and wall rocks at Rødhammeren should be the gabbro.

Mr. Olesen and I agree in the metasomatic origin of the wall rocks of the Rødhammeren ores. Finding the sources of the ore-bearing solutions as well as the solutions giving rise to the special rock types accompanying the ores may be a great problem. The sulphide ore mineralizations in the Trondheim region generally occur in connection with metavolcanics – either at the border between them and the surrounding meta-supracrustals (as the Rødhammeren ores) or in the immediate vicinity of them. Moreover, they seem to occur in areas or zones which reflect great tectonic activity. Usually the ores are accompanied by a wall rock alteration which reflects a hydrothermal-metasomatic origin of most of them which may have been brought about by the tectonic activity in the area. In the Trondheim region the relationship between different lithologies, evidence of a strong tectonic activity and a comprehensive wall rock alteration in an area of sulphide ore mineralization is so close that the present author finds it more reasonable to assume a more deep-seated tectonic-metamorphic origin than a simple contact-metasomatic origin of the hydrothermal fluids which have given rise to the wall rocks and ores at Rødhammeren. The areas adjacent to the Fongen-Melshogna-Hyllingen igneous complex provide the geologist with a number of problems concerning their polymetamorphic history in relation to magmatism and tectonic events. The investigations carried out by the present author covered only part of the areas concerned, and I look forward to seeing the results Mr. Olesen and his colleagues obtain from the northern areas. I think controversies like Olesen's and my own will reach a final solution through continuous geological work in the areas.

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